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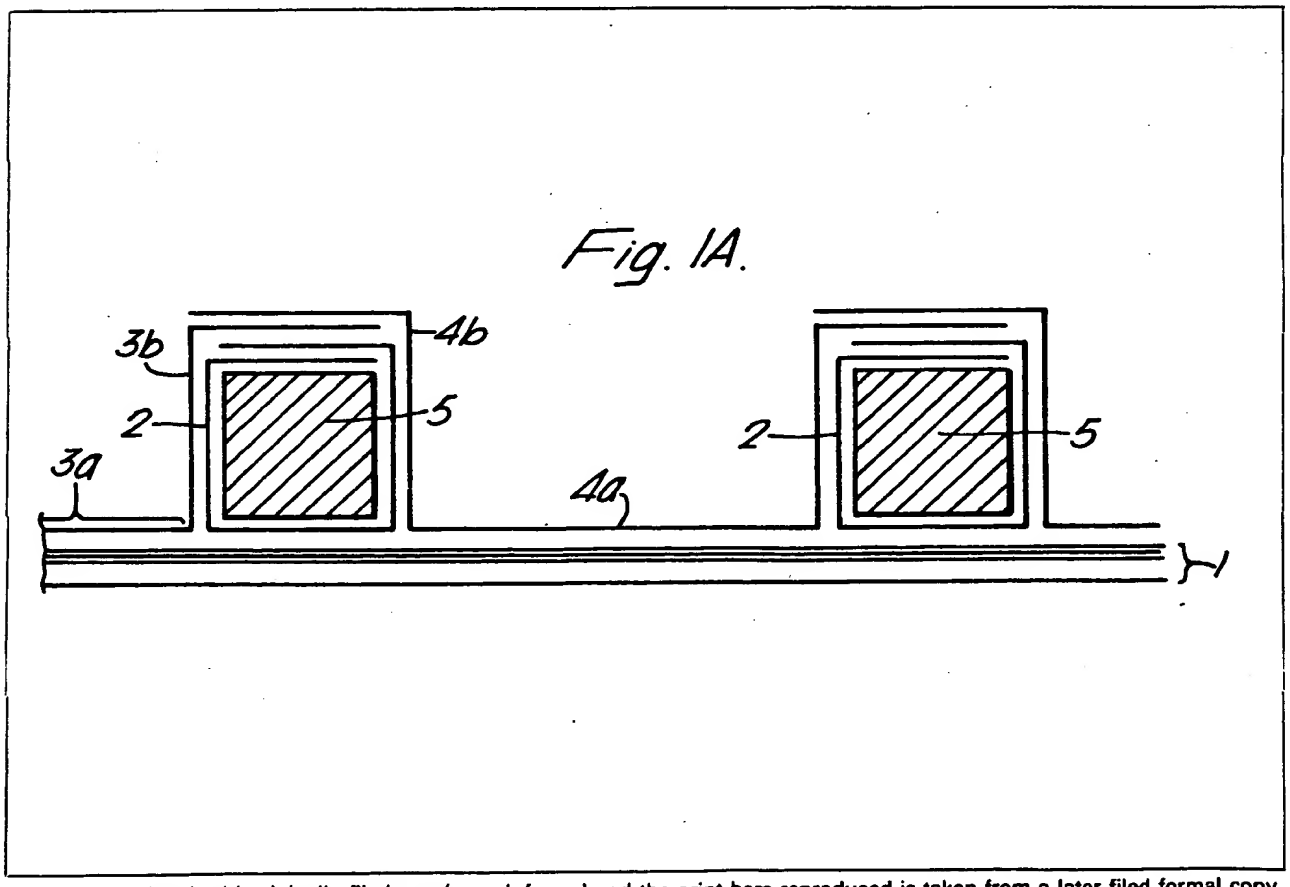
# (54) Stiffened panel of fibre reinforced plastics material

(57) A stiffened panel of fibre reinforced plastics material includes a base web 1, a stringer element 2 in the form of a strip of carbon reinforced plastics material wrapped around a mandrel 5 to define a cavity and having its lower side bonded to the base web 1. A first strip 3 is bonded along an intermediate portion 3a to the base web to one side of the stringer element 2, and along an edge region 3b to a major portion of the periphery of the stringer element 2 not bonded to the base web. A second strip 4 is bonded along an intermediate portion 4a to the other side of the stringer element 2 and at edge region 4b is bonded to the remaining portion of the periphery of the stringer element and overlaps part of edge region 3b.

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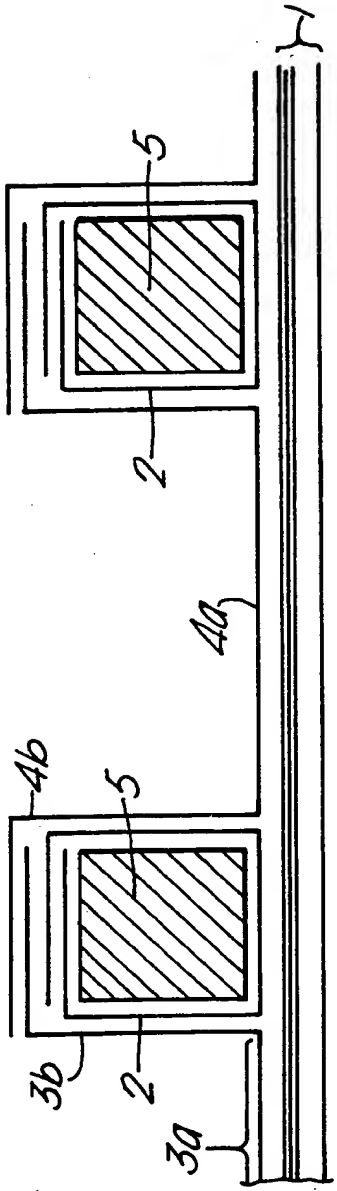



Fig. 1A.

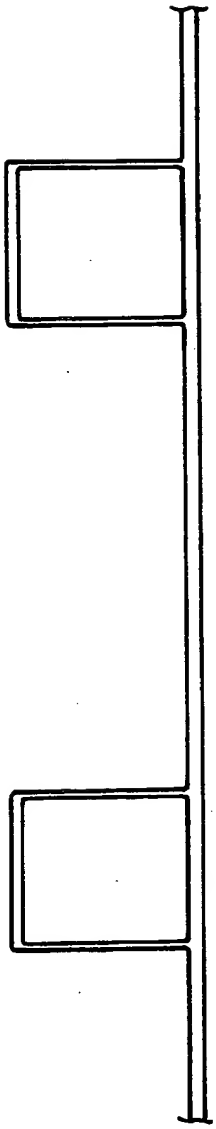


Fig. 1B.

Fig. 2A.

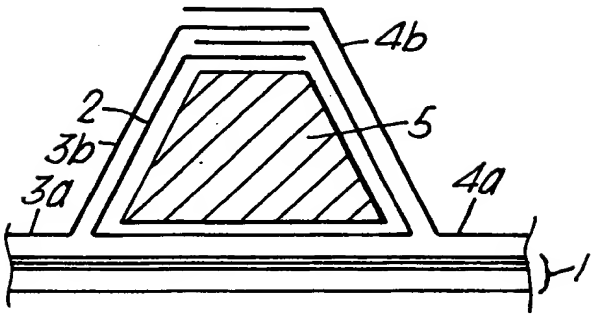



Fig. 2B.

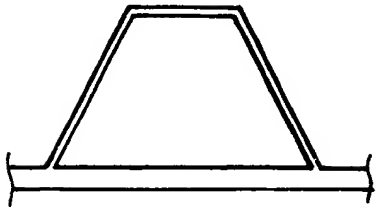


Fig. 3A.

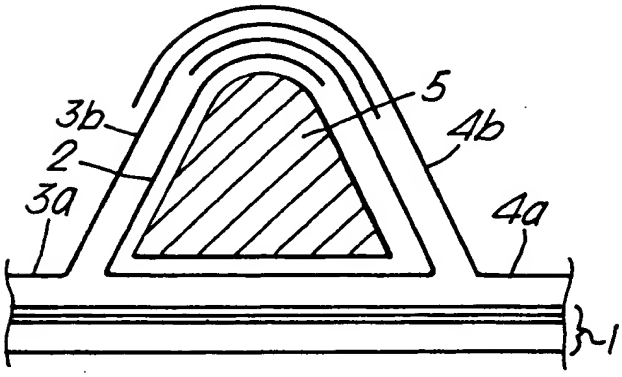



Fig. 3B.

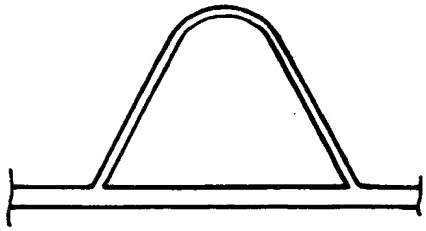


Fig.6.

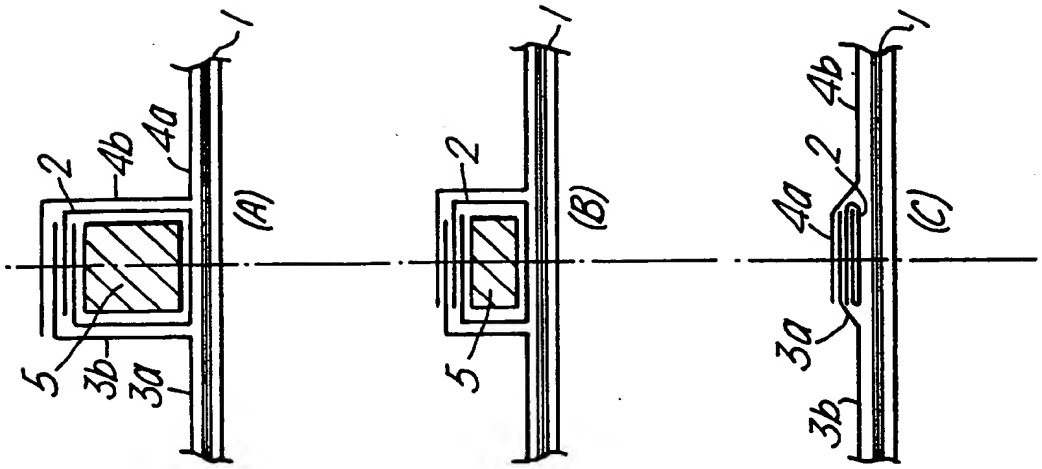



Fig.5.

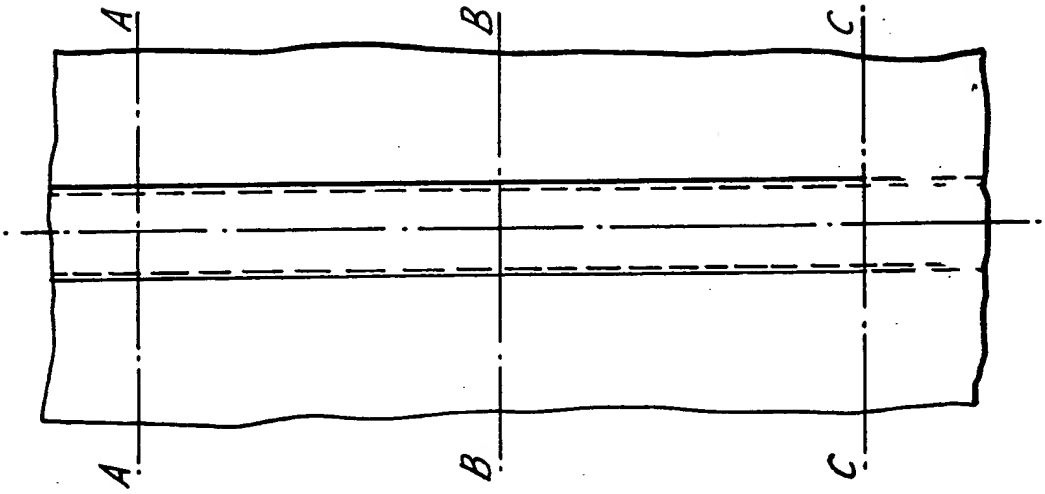
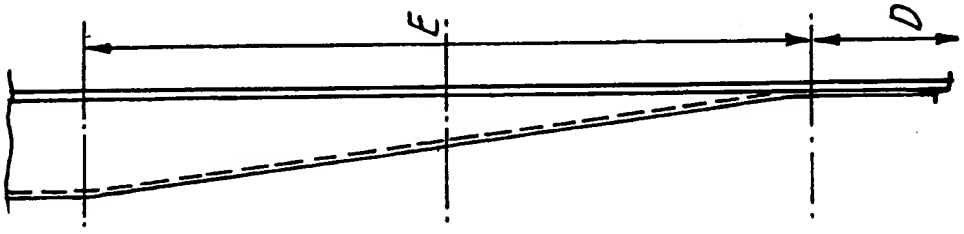



Fig.4.



SPECIFICATION

**Stiffened panel of fibre reinforced plastics material**

This invention relates to stiffened panels formed of fibre reinforced plastics material. The reinforcing fibres may be of carbon.

In our co-pending published Application No. 2,072,579A, we describe a stiffened panel which includes a base web having 'Z' section stringers integrally formed without a stringer flange as such on the surface of the base web. However, 'Z' section stringers are limited to applications where compression loadings are not particularly high. For panels which may be subjected to high compression loads, stringers of closed 'top hat' form are found to be more stable.

In the past, 'top hat' stringers have been moulded as discrete skin stringer components subsequently to be bonded to a discretely moulded base web. Alternatively, discrete skin and stringer components are laid up and cured simultaneously in a method known as co-curing.

In both these arrangements, the skin and stringer components should have similar coefficients of thermal expansion to prevent high glue line stresses occurring when the formed panel is allowed to cool after hot-curing. In the case where the base web and the stringer element are discretely moulded, any discrepancies in either moulding results in a glue line of varying thickness between the components, hence reducing the strength of the panel. Co-curing gives better control of the glue line thickness, but tooling is complicated by the fact that the stringer flange shapes must be moulded at the same time as the skin. This requires a completely shaped top tool portion and the flanges of the stringer so formed may be inaccurate.

In either arrangement, there are exposed resin fillets where the flanges of the stringer upstand from the base web. These are prone to cracking and may instigate peeling between the stringer flanges and the base web. On compression testing, it is common for panels so formed to fail owing to stringer detachment or flange delamination.

Moreover, the stringer flanges in either arrangement play little part in the load carrying ability of the panel as regards buckling and serve merely to attach the stringer to the base web. It is also difficult to inspect the flange areas for integrity of the flange joints.

According to one aspect of this invention, there is provided a stiffened panel which includes a base web, a stringer element enclosing a cavity, part of the outer periphery of the stringer element being bonded to a first surface of the base web, at least one strip bonded to substantially the remainder of the periphery of the stringer element and to the first surface of the base web, th base web, stringer element, strip or strips each being of fibre-reinforced plastics material.

The stiffened panel preferably includes first and second strips having respective interm diate portions bonded to the first surface of the base web, one to each side of the stringer element, the first strip having an edge region which extends around and is bonded to a major portion of that part of the outer periphery of the stringer element not bonded to the base web, and the second strip having an edge region which extends around and is bonded to substantially the remainder of that part of the outer periphery of the stringer element, and overlapping and being bonded to at least part of the edge region of the first member.

Preferably, the stringer element comprises a strip of fibre reinforced plastics material wrapped around to enclose said cavity.

The stiffened panel may be provided with a connecting region arranged to allow connection to a further structural element, and a transition region leading to the connecting region, the cross-section of the cavity enclosed by said stringer element progressively decreasing in the transition region so that eventually the connecting region is provided wherein opposed inner surfaces of the stringer element lie against each other.

According to another aspect of this invention, there is provided a method of producing a stiffened panel which includes the steps of

(1) preparing a base web of uncured fibre-reinforced plastics material,

(2) wrapping a strip of uncured fibre reinforced plastics material around a mandrel to define a stringer element,

(3) locating the stringer element with part of its periphery contacting a first surface of the base web,

(4) laying at least one sheet of uncured fibre-reinforced plastics material over the stringer element and adjacent portions of said first surface of the base web,

(5) curing the assembly whilst urging the sheet against the stringer element and the base web by means of a fluid pressure medium and

(6) withdrawing the mandrel.

By way of example only, certain specific embodiments of this invention will now be described in detail reference being made to the accompanying drawings, in which

*Figures 1a and 1b* are end views of a first embodiment of stiffened panel before and after moulding respectively,

*Figures 2a and 2b* are end views of a second embodiment of stiffened panel before and after moulding respectively,

*Figures 3a and 3b* are end views of a third embodiment of stiffened panel before and after moulding respectively,

*Figure 4* is a side view of a fourth embodi-

ment of stiffened panel showing a connecting region and a transition region,

*Figure 5* is a plan view of the panel of Fig. 4; and

*Figures 6a, 6b and 6c* are cross-sectional views on lines A–A, B–B and C–C respectively of Fig. 5.

Referring initially to Figs. 1a and 1b, a stiffened panel has a base web 1 of carbon reinforced plastics material, a stringer element 2 in the form of a strip of carbon reinforced plastics material wrapped around with its edges overlapping to provide a generally square cross-section having a double-thickness region along the upper side of the square and bonded along its lower side to the upper surface of the base web 1. A first strip 3 of carbon reinforced plastics material having an intermediate region 3a and an edge region 3b is bonded along its intermediate region to the base web 1 to one side of the stringer element 2. The edge region 3b extends along and is bonded to two sides of the stringer element 2. A second strip 4 of carbon reinforced plastics material having an intermediate region 4a and an edge region 4b is bonded along its intermediate region to the base web 1 to the other side of the stringer element 2. The edge region 4b of the second strip extends along and is bonded to the remaining side of the stringer element and overlaps at least part of the edge region 3b of the first strip as shown in Fig. 1a.

Referring now to Figs. 2 and 3, there are shown further embodiments of stiffened panel generally similar to that shown in Fig. 1, the primary difference being in the shape of the stringer element. In these Figures like parts are given like references.

Referring to Figs. 4 to 6, a connecting region is denoted by Arrow D and a transition region denoted by Arrow E. The connecting region enables the panel to be structurally connected to other structural members (not shown), whilst the transition region blends the panel proper into the connecting region with little or no loss in strength.

In the transition region, the cross-section of the stringer element 2 gradually diminishes towards the connecting region, but is still of the same form as the stringer elements in the previous embodiments, that is including a lower side bonded to the base web and an upper side of double thickness.

In order to produce the stiffened panels shown in the Figures, the base web 1 is laid up from pre preg sheet in accordance with the conventional methods used for flat laminates. The stringer element 2 is laid up from pre preg sheet around a core mandrel 5 which is the shape of the stringer cavity. The core mandrel may be moulded of a silicone rubb r material. The stringer elements 2 and associated core mandrels are positioned at th re-quired pitch positions along the bas web 1. Tailored pre preg strips are then positioned in sequence over the stringer elements and the base web from left to right as viewed in the Figures, so that each stringer element is contacted by a first and a second strip as mentioned previously.

The assembly is then cured whilst urging the first and second strips 3 and 4, the stringer element 2 and the base web together using a vacuum/pressure bag, and the mandrel removed. Naturally, for producing a transitional region as shown in Figs. 4 to 6, a tapered mandrel is used.

As mentioned above, the stringer element 2 includes a region of double thickness; due to the tube type of layup, the fibre orientations of the overlapping portions will coincide, thus a + 45° lay up will result in both overlapping portions being + 45°. Moreover, in the embodiments shown, there are no coincident fibre discontinuities in adjacent layers of carbon reinforced plastics material.

When laying up a panel prior to curing, the stringer element 2 and the strips 3, 4 are preferably balanced with the lower side of the base web as viewed in the Figures so that built-in stresses do not occur after hot-curing.

The illustrated arrangements provide certain advantages which can be summarized as follows:

1. Provided that the various layers of the panel are balanced, a greater choice of orientation of fibres in the various layers is available. The top part of the stringer element is thicker than in conventional panels thus moving the neutral axis further from the base web to give enhanced resistance to buckling.

2. A shaped top tool portion is not necessary and curing may be effected using a vacuum/pressure bag, the only tooling required being a suitable base plate to support the panel and mandrels moulded to the shape of the stringer cavities.

3. There are no exposed resin fillets at the stringer element base web interface.

4. There are no stringer flanges as such and the moulded base web is of constant thickness; compared to conventional 'top hat' stringers, there are no redundant flanges.

5. A stiffened panel may be produced for connection to other structures using the embodiment illustrated in Figs. 4 to 6.

6. The panel is readily inspectable.

In the illustrated arrangements, first and second discrete strips have been used; this is preferred in order to reduce the size of the resin fillet between the base web, the upstanding portion of strip 3, 4 and the stringer element, and also to provide a relatively thick upper web to the finished stringer element to provide increased resistance to buckling. However, if a relatively thick upper w b is not necessary, a single strip may b used if the nature of th strip is such as to allow a relatively small fill t.

On the other hand, further strips may be overlaid on the arrangements illustrated in the Figures as necessary to give a desired degree of resistance to buckling. For example, further tailored pre preg strips could be positioned over the arrangement of Fig. 1A from right to left as viewed in the Figure, prior to curing, so that the top section of the stringer element comprised six layers of fibre-reinforced material.

CLAIMS

1. A stiffened panel which includes a base web, a stringer element enclosing a cavity, part of the outer periphery of the stringer element being bonded to a first surface of the base web, at least one strip bonded to substantially the remainder of the periphery of the stringer element and to the first surface of the base web, the base web, stringer element, strip or strips each being of fibre-reinforced plastics material.

2. A stiffened panel according to Claim 1, which includes first and second strips having respective intermediate portions bonded to the first surface of the base web, one to each side of the stringer element, the first strip having an edge region which extends around and is bonded to a major portion of that part of the outer periphery of the stringer element not bonded to the base web, and the second strip having an edge region which extends around and is bonded to substantially the remainder of that part of the outer periphery of the stringer element and overlapping and being bonded to at least part of the edge region of the first member.

3. A stiffened panel according to Claim 1 or Claim 2, wherein the stringer element comprises a strip of fibre-reinforced plastics material wrapped around to enclose said cavity.

4. A stiffened panel according to any of the preceding Claims, wherein the panel is provided with a connecting region, arranged to allow connection to a further structural element, and a transition region leading to the connecting region, the cross-section of the cavity enclosed by said stringer element progressively decreasing in the transition region, so that eventually the connecting region is provided wherein opposed inner surfaces of the stringer element lie against each other.

5. A method of producing a stiffened panel which includes the steps of

(1) preparing a base web of uncured fibre-reinforced plastics material,

(2) wrapping a strip of uncured fibre reinforced plastics material around a mandrel to define a stringer element,

(3) locating the stringer element with part of its periphery contacting a first surface of the base web,

(4) laying at least one sheet of uncured fibre-reinforced plastics material over the stringer element and adjacent portions of said first surface of the base web,

(5) curing the assembly whilst urging the sheet against the stringer element and the base web by means of a fluid pressure medium and

(6) withdrawing the mandrel.

6. A stiffened panel substantially as hereinbefore described with reference to and as illustrated in any of the accompanying drawings.

7. A method of producing a stiffened panel substantially as hereinbefore described with reference to and as illustrated in, any of the accompanying drawings.

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